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COMPARISON OF RHESUS AND HUMAN SPECTRAL DYNAMIC VISUAL ACUITY.(U)

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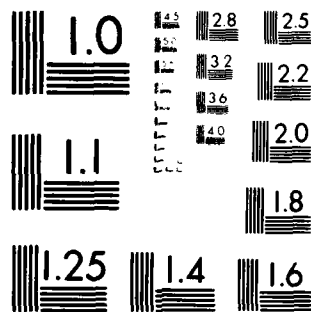
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COMPARISON OF RHESUS AND HUMAN SPECTRAL DYNAMIC VISUAL ACUITY

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Comparison of Rhesus and Human Spectral Dynamic Visual Acuity
--Zwick et al

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Janet Marshall 19 Apr 82
(Signature and date)

COMPARISON OF RHESUS AND HUMAN SPECTRAL DYNAMIC VISUAL ACUITY

ABSTRACT

The visual acuity of humans and rhesus monkeys is quite comparable for stationary targets. However, in many situations visual acuity is required for targets that are moving rather than stationary. In this experiment, we have measured the dynamic visual acuity function for the rhesus and compared it with the dynamic visual acuity for the human. For targets that are achromatic, the rhesus and human are quite comparable, although the rhesus seems to have somewhat better acuity for targets that are moving at the upper velocity extremes. When measurements were made with chromatic targets, however, certain differences appeared across species. In the short end of the spectrum, the "blue" region, the rhesus is somewhat superior in its acuity for high velocity targets; in the long end of the visible spectrum, the rhesus appears somewhat weaker in its ability to resolve rapidly moving targets. These differences are not inconsistent with recent observations of spectral differences between human and rhesus reported for static acuity measurements.

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COMPARISON OF RHESUS AND HUMAN SPECTRAL DYNAMIC VISUAL ACUITY

Many comparisons of rhesus and human visual acuity have been made (1-3). The general results of these studies suggest that these two species are quite similar in their respective maximal acute visual function. In the most recent work, Cavonius and Robbins (4) showed slight species differences in acuity for bright versus dim achromatic targets located at the extremes of the luminance acuity function. These differences were attributed to differences in the ocular optics between human and rhesus rather than to differences in retinal processing of spatial information. However, in similar comparisons made with spectral acuity targets, especially those requiring foveal function, a difference in foveal spatial resolution between the human and rhesus was suggested (5,6). Comparisons of rhesus monkey and human spectral sensitivity for spatial resolution criteria revealed a long wavelength insensitivity in the rhesus (5). The rhesus long wavelength insensitivity was especially apparent for spatial resolution criteria that measured foveal function (6,7).

These comparisons have been made with stationary acuity targets. Primate vision, however, involves motion as well as spatial resolution of targets. The ability to resolve spatial detail in moving targets is known as dynamic visual acuity. Measurements of achromatic dynamic visual acuity function in both human and macaque have shown that visual acuity decreases with increasing target velocity. This loss in acuity, however, is not simply related to target eccentricity from the fovea (8). Both retinal location as well as movement of the target image on the retina have been implicated in the explanation of the dynamic visual acuity function (9).

In the present study, comparisons of rhesus and human achromatic and chromatic dynamic visual acuity functions were made. Achromatic functions were compared with previous measurements of macaque and human dynamic visual acuity. Chromatic acuity measurements in both human and rhesus were made to determine the control that local retinal spectral mechanisms might have in dynamic visual acuity. The present work suggests a species difference in foveal function for resolution of chromatic moving targets.

METHODS

Negative contrast conventional Landolt rings and gapless rings were used as the test targets for all stationary and dynamic acuity threshold determinations. The gaps in the rings, which served as the discriminative stimuli, were always one-fifth the outer ring diameter. The visual angle subtended by the rings could be varied from 0.28 to 17.0 minutes of arc in approximately equal log steps. A size graded series of Landolt rings and gapless rings was composed with one Landolt ring randomly imbedded in a group of 3 or 4 solid rings which were equal in all dimensions. The intensity and wavelength of the acuity targets were controlled by using neutral density and narrow band interference filters. All monochromatic filters were equated to deliver the same quantal flux as that delivered at 420 nm.

Four animals were trained on the dynamic acuity task by linking a series of complex temporal visual responses (10). In the final behavioral procedure, a fully trained animal was required to depress a response lever and hold it down for a variable interval of time (<3 sec) before an acuity target (either a Landolt ring or a gapless ring) appeared on a rear projection tangent screen in front of the animal. The acuity targets could be presented stationary or moving in a horizontal path across the screen at various velocities from 5 degrees/sec to a maximum of 173 degrees/sec. For target velocities from 0 degrees/sec to 87 degrees/sec, the exposure duration for the acuity targets was 400 msec. At velocities faster than 87 degrees/sec the shutter duration was progressively reduced, due to the constraints imposed by the fixed size of the screen, to a minimum of 200 msec. If the animal released the response lever following the offset of the acuity target, two additional response panels were turned on, displaying a Landolt ring and a gapless ring. For liquid reinforcement, the animal was required to match his response on the appropriate response panel with the stimulus that had just been presented on the tangent screen. Initial training was done with the largest ring diameter targets. Following generalization for very small stimuli, threshold measurements of acuity at various velocities were determined using an "up and down" procedure (10). Data were also collected on one human subject who had considerable experience on the dynamic visual acuity task. All experimental conditions were identical for the rhesus and human subjects, with the exception that no liquid reinforcement was delivered to the human for correct responses. The termination of a white noise background provided the cue for all correct responses. Human psychophysical measurements were made in an identical manner to those described for rhesus.

RESULTS

In Figure 1 comparative data are presented for achromatic "white light" targets. In our rhesus, measurements of the dynamic visual acuity function made shortly after generalization, before much overtraining was given, showed an accelerating acuity loss above 90 degrees/sec. In contrast, with several more months of training emphasizing faster velocities, the function became much flatter, showing acuity of about 2 minutes of arc at velocities as high as 173 degrees/sec. This figure reveals that our "early" rhesus data are quite similar to the function obtained with humans by Ludvigh and Miller (8), whereas our "late" function (measured in the same animals 2 months later) is much closer to measurements reported by Barmack (11) for both human and macaque white light dynamic acuity functions. The human function obtained in our apparatus is also more similar to the function obtained by Barmack (11) than to that obtained by Ludvigh and Miller (8).

Spectral dynamic visual acuity data for one rhesus and one human are presented in Figures 2 and 3. Measurements of dynamic visual acuity functions for monochromatic targets equated for quantal flux revealed a differentiation of slope with wavelength (Figure 2). For short wavelengths, both rhesus and human acuity improved with slow target movement, with the human showing better acuity than the rhesus at velocities below 52 degrees/sec. Above this velocity the rhesus tended to show superior acuity. As wavelength was increased to 560 nm the human observer achieved a more substantial improvement in acuity for the higher velocities, obtaining at all velocities a slightly finer acuity level than that achieved by the rhesus. The curves however, show a similarity in slope as well as in absolute acuity, as was evident for the achromatic tests. A more rapid decline in rhesus acuity became evident at slower velocities for wavelengths longer than 560 nm, while the human tended to show a less significant acuity loss, noticeable only for the longest wavelengths tested.

In Figure 3, comparative spectral response curves derived from the monochromatic dynamic visual acuity functions for criterion movement conditions of 0 degrees/sec and 173 degrees/sec are shown. Good correspondence between rhesus and human visual acuity is shown throughout most of the spectrum for the stationary condition. As velocity was increased, spectral acuity curves showed greater discrepancy, especially in the long wavelengths. At 173 degrees/sec the major differences were most dramatic, with the rhesus showing poorer acuity than the human in the long wavelengths. It should also be noted that the rhesus acuity for this velocity is slightly better than the human in the short end of the spectrum below 460 nm.

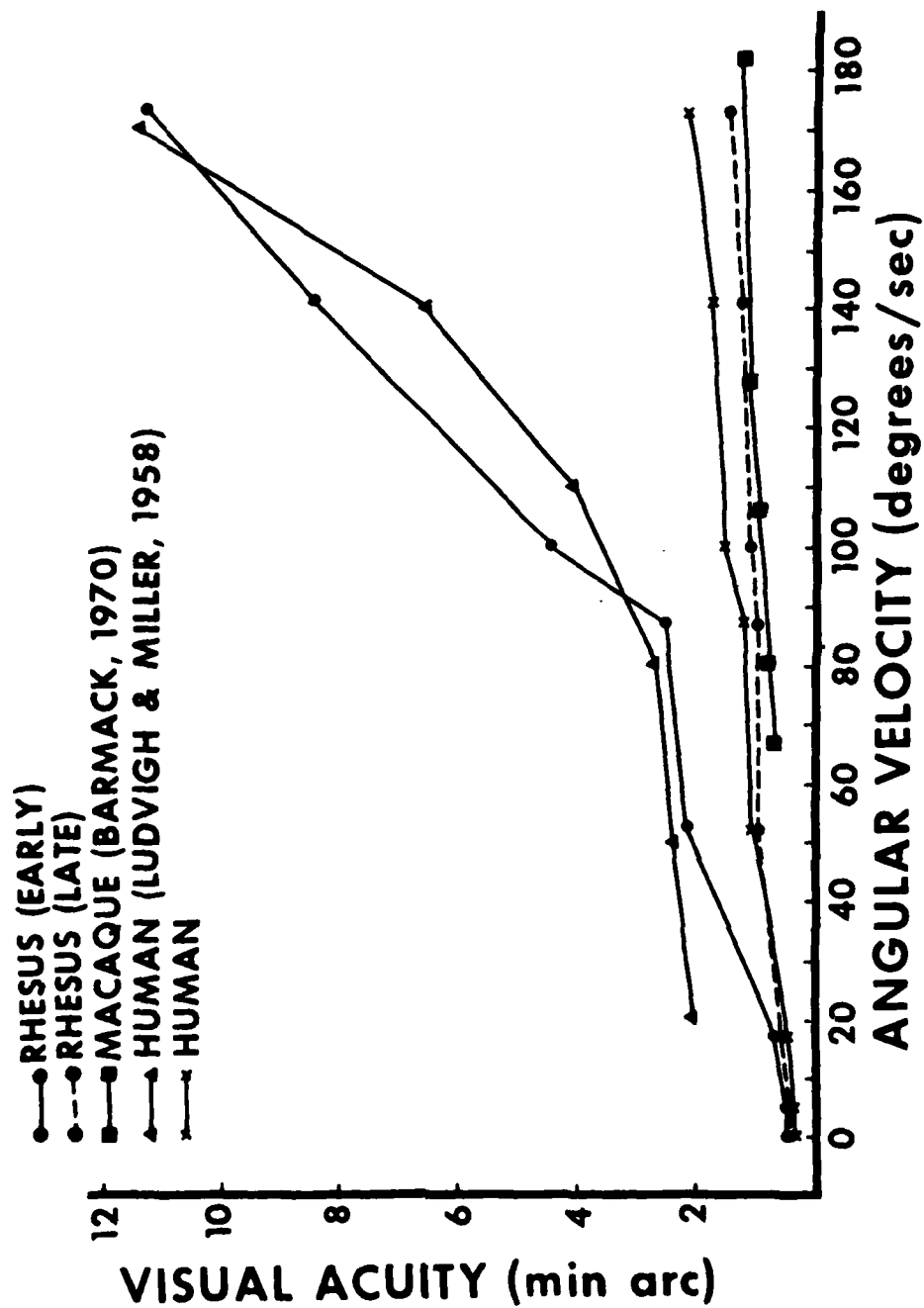


Figure 1. Man and macaque white light visual acuity compared with findings from previous studies. Effect of practice is noted when two rhesus functions "early" and "late" from this study were plotted for comparison.

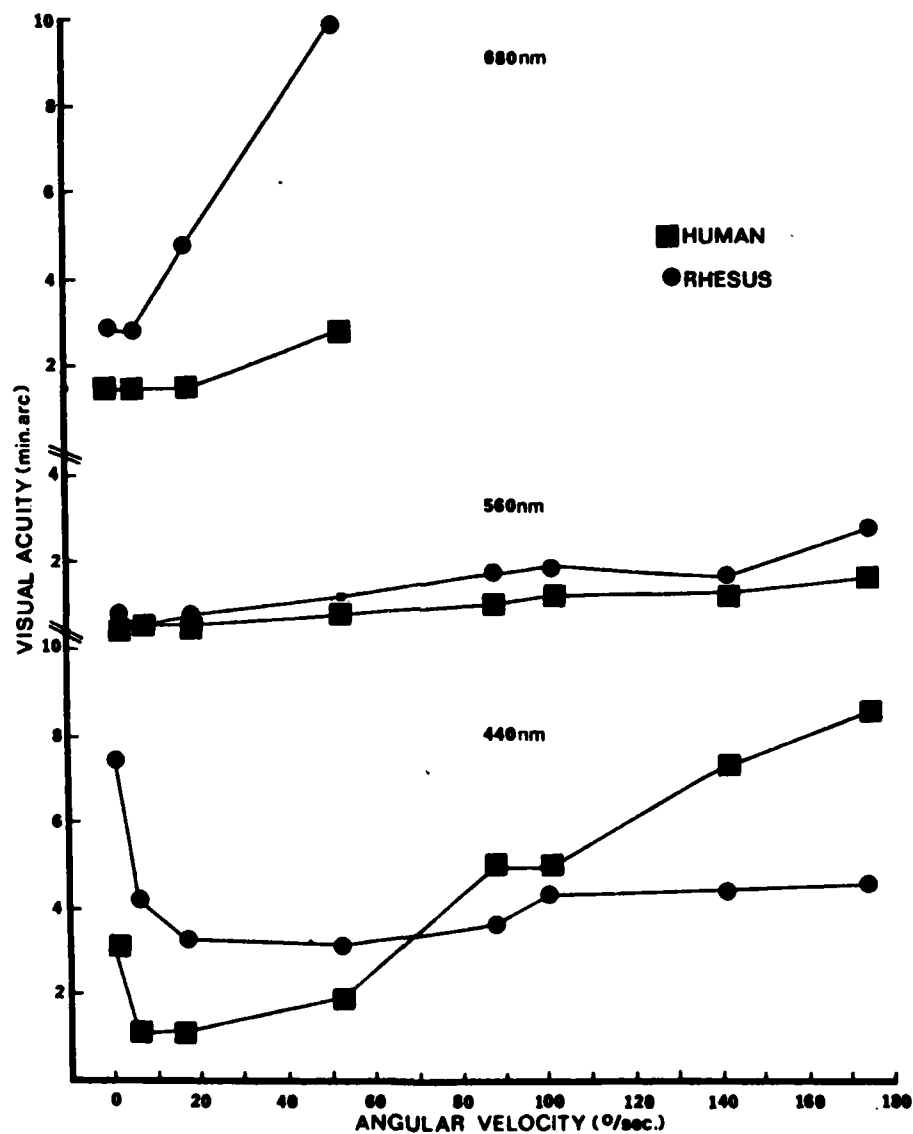


Figure 2. Comparison of spectral dynamic acuity functions for one rhesus and one human subject in selected regions of the visible spectrum. In the long wavelength regions of the spectrum, rhesus acuity for rapidly moving targets was inferior to that of the human subject, while the rhesus showed a slight superiority for the short wavelengths, especially in the deep "blue" region of the spectrum. The species tended to be similar in the intermediate spectral region.

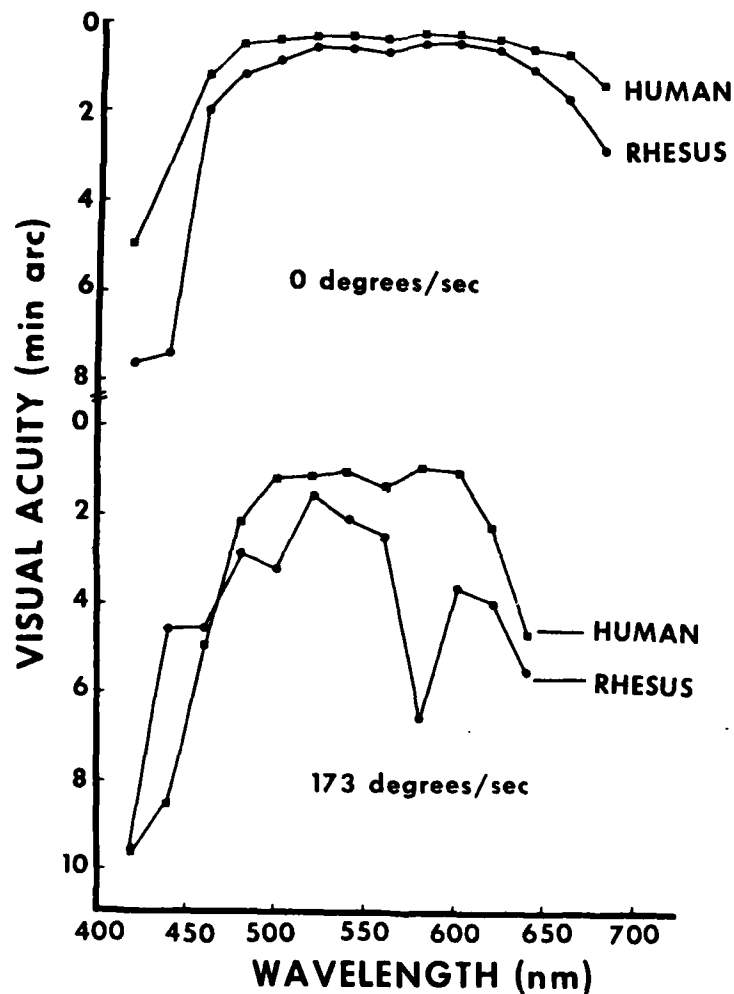


Figure 3. Spectral response functions derived from spectral dynamic acuity functions for two target velocity conditions. For the stationary target, some difference is observed in the spectral extremes. For the rapidly moving target (173 degrees/sec) rhesus acuity is observed to fall off much more dramatically in the long wavelength region than the human acuity. This trend was noticeable systematically in similar curves at slower velocities not shown here. A slight superiority of the rhesus over the human is also noted for the faster velocities in the short wavelength region.

DISCUSSION

In agreement with previous studies of dynamic acuity, our data show that considerable improvement in acuity occurs with overtraining. We observed that the maximal practice effect on the white light dynamic visual acuity function occurred at the higher velocities, which was also observed in previous investigations. Comparisons of human observers tested in the same apparatus as rhesus subjects, as was done in the present experiment and in that of Barmack's (11), indicate a slight superiority of the macaque at the higher velocity range of the achromatic dynamic visual acuity function.

Similarly, comparisons of spectral measurements of rhesus and human in the present experiment, measured under identical test conditions, suggest that these species show very similar but not identical general spectral functions. Both the rhesus and the human show a non-uniformity of slope of the dynamic visual acuity function across the spectrum. The slope of the dynamic acuity function for both species is steeper in the long end of the spectrum, the red end, than in the blue region of the spectrum. Both the rhesus and human functions in the short wavelength region of the spectrum suggest that the acuity for slow moving targets may be slightly better than for stationary targets. Such effects have been reported in previous human achromatic dynamic acuity functions (9) and have been related to the well known Troxler effect (In the peripheral retina, at low luminances, steadily fixated targets tend to perceptually disappear. If such targets are slowly moved, they are perceived again.)

Comparison across species suggests that differences in spectral function reported in previous experiments are also observable in the present experiment. The rhesus has generally been reported to have a greater sensitivity than man to blue light (12,13). The rhesus' superior acuity at shorter wavelengths for higher velocities may be due to a greater parafoveal sensitivity than the human (11). This sensitivity difference, along with an advantage in eye movement latency and speed, may account for the rhesus' greater capability to resolve white light targets at high velocity.

On the other hand, the rhesus appears slightly inferior in acuity to the human in the long wavelength region of the spectrum, the red region, especially at the higher velocities. Our human subject was capable of maintaining foveal acuity (1 minute of arc) much more consistently in the long wavelength end of the spectrum than was our rhesus subject. This apparent discrepancy could be due to differences in long wavelength foveal sensitivity between rhesus and human as previously reported (5-7).

CONCLUSION AND RECOMMENDATION

None

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